PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California

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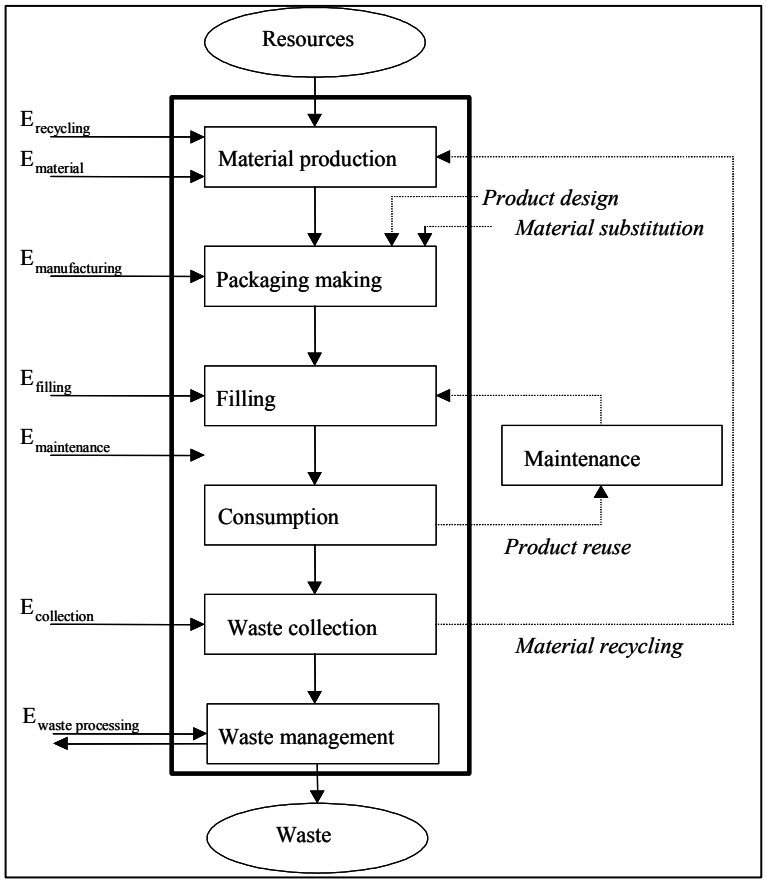
The Issue

In their quest to reduce energy usage, greenhouse gases (GHGs), and other power plant emissions, researchers have studied the energy use and accompanying emissions associated with many consumer products. This work has led to numerous products that use energy more efficiently; in fact, the U.S. Environmental Protection Agency's ENERGY STAR® program lists thousands of energy-efficient products in more than 40 categories.[1]

Less studied, however, is the amount of energy used during the full life cycle of the product—that is, the energy used to produce it, operate it through its useful life, and ultimately dispose of it or recycle it. Each segment of that life cycle offers opportunities for saving energy and further reducing emissions. One study of California's energy efficiency potential estimated that implementation of a full spectrum of



Energy consumption throughout the lifecycle of materials. Energy is used to manufacture the material and product, use and transport the product, and manage the product at the end of its useful life.

[1] U.S. Environmental Protection Agency. Accessed August 24, 2005. ENERGY STAR® website. www.energystar.gov/index.cfm?fuseaction=find_a_product.

energy efficiency activities could reduce the state's peak electricity demand by as much as 15,000 megawatts.[2]

Product life-cycle optimization is a process that can be used to help reap these energy and emissions reductions. In this process, researchers evaluate the production, use, and disposal of a consumer product and use the resulting information to reduce the cradle-to-grave environmental burdens (including energy use and GHG emissions) associated with that product.

Project Description

PIER-EA funded this research project to explore the potential role of product life-cycle optimization to help reduce GHG emissions in California. The research team identified the largest manufacturing sectors in California using information on value added and total value of shipments in California. This information was then used to provide guidance for identifying major products produced in California. The 50 products chosen span a wide cross-section of California's manufacturing output and include such diverse items as personal computers (PCs), cheese, aircraft, wine, carpet, gasoline, and paint. All products have GHG emissions associated with their production and disposal; some products also have GHG emissions associated with their use. In addition, some products can be recycled at the end of their life, thus reducing product-specific GHG emissions.

From the 50 products selected for this analysis, the research team found that the top 20 GHG-emitting products (from a life-cycle perspective) were: airplane, large industrial water pump, semiconductor process machine, car, commercial refrigerator, gas stove and range, air conditioner, metal window, tape storage drive, personal computers (PCs), hydraulic cement, asphalt paving mixture, microwave oven, wooden table, semiconductor chip, ready-mix concrete, scanner, printed circuit board, tires, and bicycle.

Explorative case studies to identify opportunities for GHG emissions reduction—as well as to identify practical policy options in California for promoting life-cycle optimization—were then conducted for PCs, and for cement and concrete. The case studies estimated GHG emissions in California from the manufacture, use, and disposal of the products considered. The case studies identified opportunities for reducing emissions throughout the life cycle of these products, quantifying the potential GHG reductions in California. Researchers recommended a number of potential policy initiatives that could be promoted to reduce the GHG emissions associated with PCs and cement and concrete in California.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound electricity.** Reducing energy use over the life cycle of consumer products will result in reduced electricity use, fuel use, GHG emissions, and criteria pollutants from power generation. As a result, this work will lead to improved air quality and lower statewide energy use. The total potential of these savings depends on

[2] Rufo, M., and Coito, F. September 23, 2002. *California's Secret Energy Surplus: The Potential for Energy Efficiency.* The Energy Foundation and The Hewlett Foundation. www.energyfoundation.org/energyseries_secret.cfm.

the type of product manufactured, the current efficiency within each product life-cycle stage, and the costs and benefits of the efficiency opportunities available in California.

- **Providing reliable electricity.** Reduced overall energy use helps California meet growing demand.
- **Providing affordable electricity.** Lowering the demand for electricity in California will reduce the investment necessary to develop additional power generation capacity in the state.

Results

The life-cycle optimization approach enables researchers to identify mitigation options beyond those that are more commonly recognized, and provides policymakers with a wider breadth of information regarding both GHG emissions sources in California and potential mitigation options.

The study identified a number of life-cycle GHG emissions mitigation options for PCs and cement and concrete, and it provided estimates of annual potential GHG emissions reductions if these options were implemented.

The PC case study estimated that the total life-cycle GHG emissions associated with PCs in California amount to roughly 5.9 million tons of carbon dioxide (Mt CO_2) (which is equal to 1.61 million tons of carbon, or Mt C) per year. The research team identified a number of opportunities for reducing GHG emissions from PC manufacture, use, and disposal in California. Opportunities include increasing the energy efficiency of California's clean rooms, reducing perfluorocompound emissions from semiconductor manufacturing facilities, increasing the utilization of PC power management features in California homes and businesses, improving PC recycling rates, and upgrading PCs to extend their useful life. Together, these opportunities could potentially save over 2 Mt CO_2 (0.5 Mt C) in California each year.

The cement and concrete case study estimated that the total life-cycle GHG emissions of cement and concrete in California amount to roughly 11.8 Mt CO_2 (3.2 Mt C) per year. As in the PC case study, the research team identified a number of opportunities for reducing the life-cycle GHG emissions of cement and concrete in California. Opportunities include increasing the energy efficiency of cement manufacture, using waste fuels in cement kilns, using blended cements, and increasing the rates of concrete recycling in California. The total technical potential for GHG reduction in California associated with the identified opportunities is nearly 2 Mt CO_2 (0.5 Mt C) each year.

Combined, the mitigation opportunities identified in these two case studies have an estimated technical potential to reduce GHGs in California by nearly 4 Mt CO_2 per year, which is about 1% of the state's 1999 net GHG emissions of 398 Mt CO_2.

That such opportunities still exist in California for reducing the life-cycle energy use and GHG emissions of the case study products suggests that there are considerable economic and energy losses. A life-cycle optimization evaluation for other products produced in California could undoubtedly identify many other potential options for reducing GHG emissions. To the extent that these potential reductions are related to inefficient use of materials or energy, reducing this

waste can be an important driver for improving competitiveness in a globalizing business environment, while also addressing environmental problems such as climate change, air pollution, and waste export.

Final Report

The final report on the results of this work, *Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California* (CEC-500-2005-110-F), is available at: www.energy.ca.gov/pier/final_project_reports/CEC-500-2005-110-F.html.

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